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Devices Without Borders: What an Eighteenth-Century Display of Steam Engines can Teach Us about 'Public' and 'Popular' Science

LISSA ROBERTS
Center for Science, Technology, Health and Policy Studies, University of Twente, Enschede, 7500AE, Netherlands
E-mail: l.l.roberts@utwente.nl

Abstract. This essay details a public display of four steam engine models assembled in a Leiden orphanage courtyard in 1777. By examining the multiple purposes to which these engines were and could be put, alongside the various interests, goals and interpretations of their inventors, instructors and audience, the notion of a clear division between public and private as well as scientific research and popularization is questioned. In its place, the essay ends with a generalized image of modern science, its practitioners, users and audiences seen as a complex terrain in which relations and divisions are constantly asserted, contested and renegotiated.

On June 22, 1777 Leiden's newspaper, the *Leidse Courant*, featured an article that announced: "Last Thursday a public demonstration was held of a hydraulic machine invented by Mr. Blakey and donated by him to the university". It further describes the machine as a portable and economical steam engine without beam, making it especially useful for land reclamation. This is why Blakey's design received a Dutch patent.[1]

The article is remarkable for a few reasons. Generally, the newspaper consisted of one sheet printed on both sides. Politics, commerce and shipping news appeared on the front, advertisements on the back. But this promotional article appears as front-page news, while public demonstrations, lectures and entertainments were usually announced in back-page advertisements. William Blakey had worked hard to distinguish himself from contemporaries who grubbed for attention on the meaner streets of science and technology. Perhaps this article's placement provides evidence for his temporary success.[2]

Further, the article doesn't mention where the demonstration took place. Neither do the records of the institution where the demonstration was held

(*Inventaris van het Archief van het Heilige Geest of Arme Wees- en Kinderhuis te Leiden 1334–1979* #3757).[3] Leiden University records reveal that workers were hired to dig out an old well and build a stand for Blakey's machine in an orphanage courtyard near the university. Orphanage records say nothing about granting permission for an experimental workstation in the courtyard nor about whether visitors disturbed the orphanage's daily schedule.

The article is also silent about who attended the demonstration. Such information comes from other sources. A letter, for example, from an inventor named Francisco Pinto to the director of the Batavian Society for Experimental Philosophy of Rotterdam, describes an unsavory Spanish army officer whose attendance convinced him that the Netherlands was ripe for exploitation by a steam engine-bearing entrepreneur. (Rotterdam municipal archives 1778) The Danish astronomer Thomas Bugge also included the orphanage in his Dutch travel itinerary during the summer of 1777 (Bugge 1777, 28 recto). Curiously, Bugge neither mentioned the display's public nature, nor Blakey's machine. Instead, his diary corroborates university records that mention the three other machines Bugge did see:

[1] a Savery-style steam pump bought by Petrus van Musschenbroek in 1734 (Figure 1).
[2] A small-scale model of a Newcomen machine ordered by Jean Nicolas Sebastian Allamand for Leiden University's physics cabinet from the London instrument maker Edward Nairne in 1772; and [3] a larger model built for the physics cabinet by the Leiden instrument maker Jan Paauw in 1774 (Figure 2).

Bugge called these three machines the most 'remarkable' elements of Leiden University's physics cabinet. We will find that they and Blakey's machine simultaneously advertised technological novelty and timeless physical principles, fed personal interest and the public good and afforded the pursuit of both innovative research and popularization. They were, in other words, devices without borders.

We begin with Musschenbroek's modified version of Thomas Savery's steam pump, which the university purchased upon his death in 1762. The model stood 172 cm high, with a width of 72 cm and a depth of 62 cm. It sported a brass boiler and a roof for collecting water forced up through a long pipe by steam pressure.[4] Musschenbroek, then experimental philosophy professor in Utrecht, ordered it from the Amsterdam instrument maker J.S. Meijer in 1734. Initally intended for Utrecht University's physics cabinet, Musschenbroek bought and kept it in his own garden where it propelled jets of water 16 m high. Since it was common practice for professors to give private lecture courses to university students, we assume he put his pump to pedagogical purposes. Musschenbroek further extended

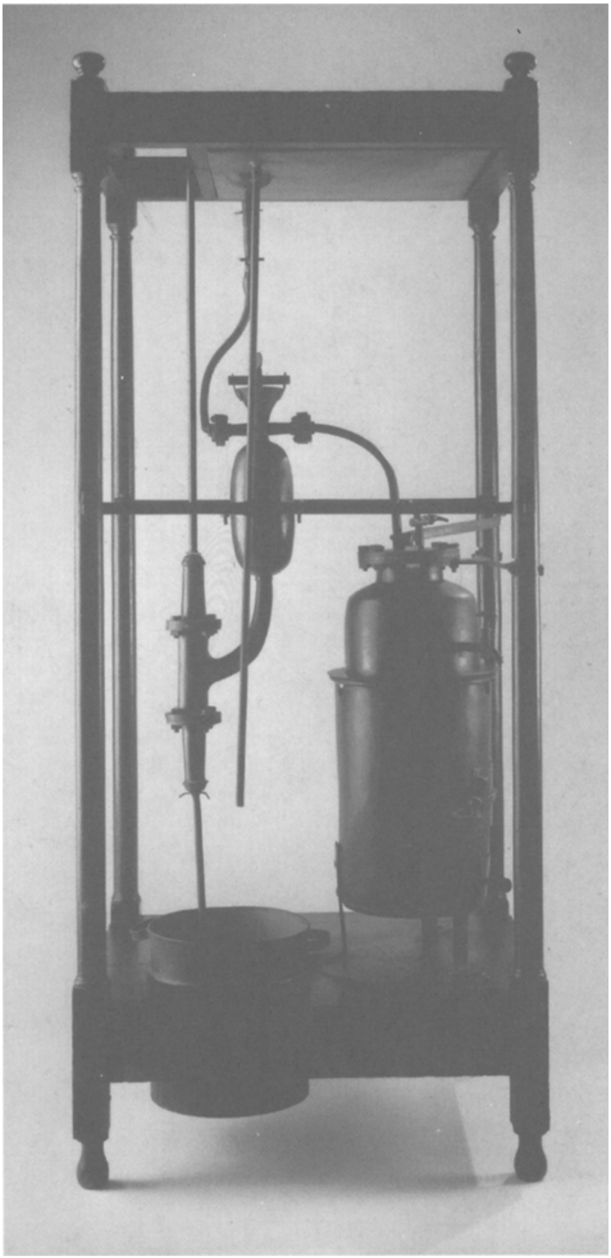

Figure 1. Model of a steam pump designed by Thomas Savery and built by the Amsterdam instrument maker Meijer, commissioned by Petrus van Musschenbroek in 1734.

his audience by discussing steam engines in his popular science text *Beginselen der Natuurkunde* (2nd edn. 1739, p. 438 and plate x). We see here that assigning demonstrations or demonstration devices a place on the

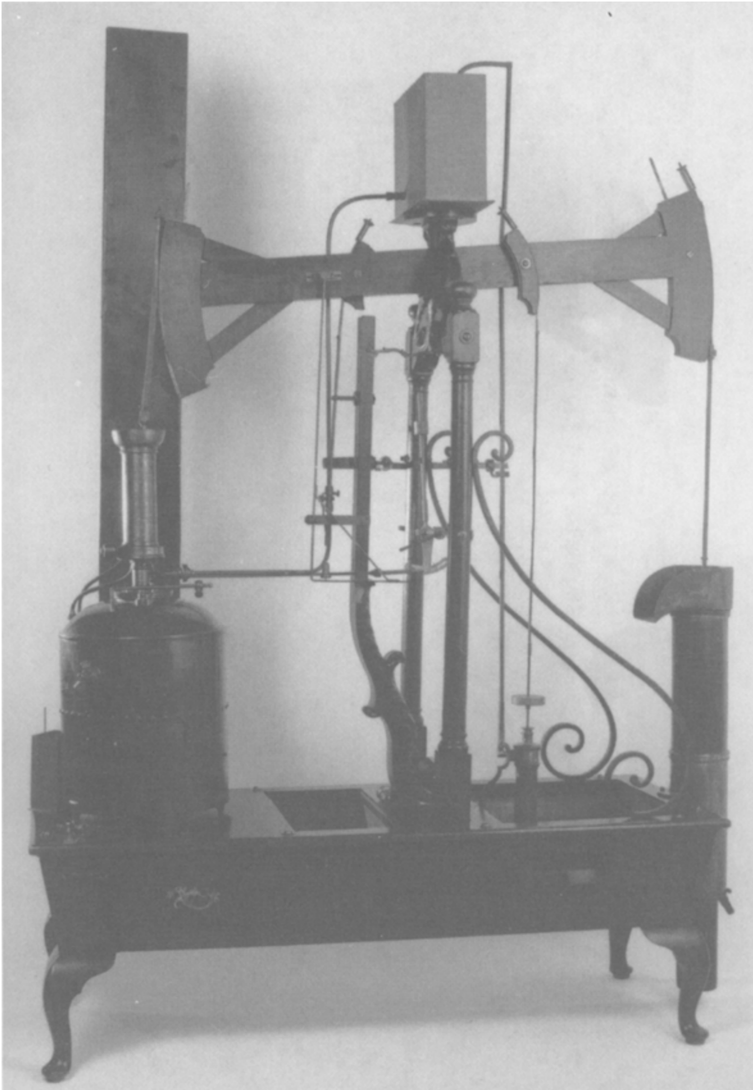

Figure 2. Atmospheric steam engine, commissioned in 1774 by Jean Allamand for Leiden Univeristy's physics theatre and built by the Leiden instrument maker Jan Paauw.

continua of private to public and investigative research to popularization can be a complicated business.

Musschenbroek took his machine to Leiden when he became professor in 1740. Leiden's physics cabinet already contained a rudimentary model steam pump – Willem 's Gravesande commissioned one in 1727 – but Musschenbroek's was more sophisticated. The earlier model was a primitive contraption used to demonstrate steam expansion and contraction for

's Gravesande's university lectures and his popular science book *Mathematical Elements of Physics confirmed by Experiments, or An introduction to Newtonian Philosophy*. It did little to celebrate the invention's technological promise.[5]

And yet, 's Gravesande procured funds for his model's purchase by claiming that steam engines would prove superior to windmills as allies in the Netherlands' struggle against flooding.[6] For him and the university governors, university science spanned the theoretical and the practical. If his model was an experimental demonstration device, so too did it represent how knowledge of nature might be put to work for public benefit. Little wonder that Musschenbroek's successor Allamand purchased the more dramatic model when it went on auction in 1762. Watching water shoot up to stunning heights was bound to convince witnesses of this engine's power. Without changing its pedagogical purpose, Allamand transferred the machine's ownership from that of a private citizen to a public institution.

Well known in the Netherlands for his knowledge of steam technology and advocacy of its adoption for water management, Allamand did not rest content with this purchase. In 1772 he ordered an exquisite Newcomen model from the London instrument maker Edward Nairne. Unlike Musschenbroek's steam pump, which was powered by steam pressure, this steam engine relied on atmospheric pressure and worked with a piston in a vertical cylinder and an overhead rocking beam. Nairne's table-top model aesthetically represented the technological progress this design entailed, but proved to be limited as a demonstration device. Only 79 cm high, 51 cm wide, and with a beam 31 cm long, its cylinder cooled down quickly; after a few strokes, the model ran out of steam. Undaunted, Allamand purchased a larger replacement (2.5 m high, 1.74 wide) from Jan Paauw in 1774. Operating on a tight budget, he agreed to pay half in cash and half in kind; Paauw now owned the Nairne model.[7]

Though we don't know for sure, it would seem that Allamand chose to move these three models – together with one donated by Blakey – to the courtyard of the *Heilige Geest* orphanage for practical reasons. The courtyard had a well from which water could be raised and a large enough space to assemble and put the models to work. On June 17, 1777 the display was opened to the public. According to university records, the machines stayed in place until 1781.

What kind of demonstrations took place in the courtyard? These models advertised the entrepreneurial inventiveness of Blakey and Paauw while providing an outdoor laboratory for university students. They demonstrated physical principles while highlighting technical innovation, attracted scientific amateurs and profit-seeking adventurers, and directed observers simultaneously toward theoretical considerations and practical application.

As was true for many displays in the eighteenth century, the boundaries between public and private, commerce and knowledge, theory and practice, science and technology, research and popularization could not be clearly drawn in the orphanage courtyard (Roberts 1999a).

Neither were such boundaries clearly set in the minds and experiences of the display's operators and observers. 's Gravesande, for example, was Europe's foremost professor of experimental physics and an entrepreneur, having contracted to market steam engines he helped design. Musschenbroek belonged to a famous family of instrument makers. Raised in an environment that mixed theory and practice, his publications made science education a public affair. Further, he, s' Gravesande and other Dutch professors advised government and commercial agencies on practical topics ranging from navigation to water management (Davids 1990; Roberts, forthcoming). Similar to French contemporaries who, as members of the *Académie des Sciences*, advised on practical matters such as patent applications as they pursued research which often stemmed from practical questions, these so-called 'scientists' lived a hybrid existence (Hahn 1971).

A similar case can be made for those who attended public demonstrations. William Eamon has traced the dynamic tension between elite privacy and vulgar publicity in the rise of natural knowledge during the Renaissance. (Eamon 1994) By the eighteenth century, commerce and the commodification of knowledge had advanced to the point that science was unthinkable without the circulation of books, instruments and advertised talent. The 'marketplace of ideas' was no mere metaphor; it was a public arena populated by savants and salesmen displaying their goods for public consumption (Schaffer 1992; Roberts 1999a).

No clear boundaries separated private from public or research from popularization in the orphanage courtyard in Leiden, showing its four steam engines to have been 'devices without borders'. As stated, the oldest model began as the private property of Musschenbroek – experimental philosopher, instrument maker, university professor and science popularizer. He modified it, experimented with it, taught students with it and advertised it in a popular science textbook. By the time it reached the orphanage, it had performed years of service, demonstrating the power generated by controlling steam expansion and contraction. Here it demonstrated 'nature' at work and showed how its force could be harnessed for public benefit to university students, many of whom went on to take up positions of authority in Dutch public and commercial life.

The size of Pauw's Newcomen model gave demonstrations clarity and drama while highlighting the innovations of its design. Students could easily see what was going on, while the machine's stamina better represented its potential for applied work. This was an important consideration that

helps explain why Allamand went to so much trouble and expense to obtain a working Newcomen model. Like his colleagues at the Batavian Society in Rotterdam who organized the public demonstration of a full-scale Newcomen engine, Allamand advocated the use of steam engines for water management and land reclamation in the Netherlands. If Batavian Society members tried to persuade government officials to adopt this technological innovation, Allamand worked on their sons, who would one day take their places (Pols and Verbruggen 1996).

This leads to a general remark about Dutch university science in the eighteenth century as represented by Leiden's physics cabinet. 's Gravesande first included machine models in the university collection, assembling a three-dimensional encyclopedia that merged the work of hand and mind. It stimulated an appreciation of nature's laws, while promoting respect for the expertise of engineers and craftsmen and manifesting the relations between their inventions and the physical principles by which they worked. As such, the physics cabinet realized an Enlightenment project. But, if the Enlightenment was a European movement with important regional variations, so did this encyclopedic project take on specific contours in the Netherlands. Diderot had advertised the *Encyclopédie* as a subversive weapon directed against the status quo, a claim taken seriously by French censors. Leiden University and its physics theater, contrariwise, were stalwart components of Dutch society. They helped maintain official culture by educating those who formed and served its dominant classes. The Dutch embraced utility as a way of bringing together various interests to create a greater whole (Davids 1990; Roberts 1999).

This was not to say that individuals ceased to promote their own interests, which brings us back to Nairne's miniature steam engine. The reader will recall that its beauty had not translated into reliable operation and that Allamand used it to pay Paauw for a large-scale replacement. Though Paauw was now the owner, he asked that it be placed in the courtyard, providing him with a valuable source of comparative information. Given his own hybrid character – Paauw was a highly regarded instrument maker and a university graduate who had studied closely with Allamand – he was well positioned to benefit from the courtyard display (Rooseboom 1950, pp. 110–112). Pauw's customers were directors of university and society physics cabinets, and wealthy private collectors. Neither category needed to be further convinced of his abilities. William Blakey, however, had yet to establish himself in the Netherlands. If published promotions as well as public demonstrations had won him support in England and France, perhaps they would work in the Netherlands too.[8]

Blakey displayed his engine before an investigative commission at the Hague in 1776 as part of his campaign to win a Dutch patent. Patent in

hand, he arranged a more public demonstration for the Batavian Society of Rotterdam. Hoping to win the society's approbation, he constructed a steam-driven water-pumping installation at Crooswijk, near Rotterdam. While he won some admirers, his demonstration did not lead to any contracts there. Visitors from Amsterdam's municipal government were, however, sufficiently impressed to commission his services. In 1778 he designed and oversaw the (ultimately unsuccessful) construction and installation of a steam driven system for cleansing the city's canals.

If we return to June 1777, we see how the Leiden demonstration fit into Blakey's strategy. As the newspaper article with which I began announced, Blakey came to Leiden as a self-proclaimed benefactor of the university. He had, after all, donated his engine to the university's physics cabinet and was on hand only to see that it was properly installed and operated. We might think of him as both playwright and director of his machine's courtyard debut. His challenge was to satisfy the critics as well as attract paying customers. But how could he accomplish this? The first step was to disengage himself from his invention, which was now university property, and to project its performance as a question of scientific interest.

The rest can best be explained in terms of what Denis Diderot contemporaneously described as the 'actor's paradox' (Diderot 1981). As Diderot put it, what passes for truth on stage is not the repetition of mundane reality, but the internal unity of action constructed by a drama's author and given life by the actor's performance. Artificiality begets natural truth, while the breakdowns of everyday life obscure it. This is the actor's paradox, but also the paradox of instrumental display. Whether Blakey's invention ultimately proved successful in the field, it needed first to win the public's sympathy and support through the artificiality of dramatic display.

Bringing the four steam engines together, we can say something about their combined courtyard appearance. Musschenbroek's machine is a perfect example of a 'device without borders'. Without any design changes, it straddled the domains of private and public property while occupying virtually every division on the spectrum that runs from investigative research to popularization. Musschenbroek experimented and taught with the machine in his private garden. But he also built a 'virtual classroom' through the publication of his *Beginselen der natuur*. Now, anyone could familiarize themselves with his apparatus by reading the book.

The lessons these steam engines were intended to embody were simultaneously theoretical and practical. Natural inquiry, as presented at the university, was used to reveal God's creation and the ways it could be applied for public benefit. Achieving these ends rested on demonstration devices that exposed the powers of nature while putting them to work in clearly observable, productive ways. Nairne's table-top model failed to do this and

was used by Allamand as currency to obtain a better working model. It took the hybrid genius of Jan Paauw, a man who made his living by working with his hands as much as with his mind, to draw out its demonstrative value.

Generally we find that success rested on partnering a professor's pedagogical dedication and the skill of a philosophically minded instrument maker. 's Gravesande had relied on Petrus van Musschenbroek's brother Jan earlier in the century (Clercq 1997). By the 1770s Allamand turned to Paauw, whose workshop had come to eclipse the Musschenbroek's. Where the university's interest ended and Paauw's began is therefore not easy to judge. Small wonder that he could use the courtyard display for his own – commercially-tinted – investigative purposes.

William Blakey's motives were thoroughly entrepreneurial, but given the nature of the Dutch market, he tried not to be too blatant about it. Gaining patrons in a country without coal or centralized authority meant cultivating those with influence where it counted – academics, scientific society members, public officials and governors of trading companies (Let us not forget that Blakey's patent covered the colonies with their sugar refineries as well.). Leiden offered a dignified stage on which to sell his wares.

Conclusion

What lessons can we draw from this story for the study of contemporary science? First, we have the question of instrumental identity. While instruments direct us toward and away from specific directions and sensations, their use is not pre-determined (Ihde 1990). In a complex world of science, technology and pecuniary interest, users adapt instruments to their own purposes, sometimes with surprising results (Kline and Pinch 1996). Further, an instrument is always tied to the negotiated meaning of the (experimental) setup in which it is placed (Pinch 1985).

What of the nature of science, considered more generally? Ever since early members of the Royal Society of London claimed that scientific knowledge must have an open and public character in order to achieve a level of 'moral certainty', guarding laboratory secrets from outside scrutiny has existed uneasily alongside the ethos of science as public property. (Shapiro 1983; Schaffer and Shapin 1985) Modern scientific knowledge differs from private opinion because it requires public validation. But the matrix in which science resides is structured by layers of professionalization, regulation and links to industry and the state that dictate research agendas and degrees of secrecy, while the broader public proclaims its right to know. The line between private and public constantly shifts through negotiation, assertions of power, and contestation.

Closely related are questions regarding the 'public understanding of science'. But recent commentators take a critical view of what 'science' and 'public' mean within this equation. John Ziman writes, "...'science' is not a well-bounded thing, capable of being more or less 'understood' ...what counts as science is sometimes defined very differently by different people – or even by the same people under different circumstances" (Ziman 1991, p. 100). Roger Silverstone adds, "There is no such thing as *the* communication of science...there is no such thing as *the* public" (Silverstone 1991, p. 106).

This raises questions about the relationship between science and popularization. If there is no single 'public' for whom science is popularized, the very nature of scientific communication needs to be reconsidered. Since the early nineteenth century, institutions were established that presented science as the realm of experts who simultaneously investigated nature, enlightened the public and upheld the moral order of society (Golinski 1992). But this image of elite expertise and public passivity has been consistently countered by extra-institutional initiative, whether in nineteenth-century pubs or the make-shift 'laboratories' of current-day computer nerds (Secord 1994). Science is always geared for an audience – whether colleagues, customers, citizens or competitors – while knowledge production and innovation circulate rather than simply radiate out from a privileged center. Both, the describing and the prescribing of these processes, require an appreciation of the rich contexts in which they take place – contexts that determine where borders appear.

Notes

1 The same text appeared on the back page of Blakey (1777).

2 The only (incomplete and error-ridden) biographical account of Blakey, is Bootsgezel (1935–1936).

3 For background on the orphanage see Dröge (1990).

4 The model is on permanent display at the Boerhaave Museum in Leiden, catalogued as inventaris nr GM 101a.

5 's Gravesande's model was described in a 1752 inventory as "Een dikke koperen pot op een ijzeren drievoet en eenig hout-gestel om de Engelsche watermachine, door damp bewogen werdende, na te maken." (A thick copper pot on an iron tripod with woodwork, made to model an English watermachine moved by steam.) *Archief van curatoren van de Leidse Universiteit* (1752).

6 Letter to Leiden University curators dated 6 February 1727. Quoted in Clercq (1987, p. 163).

7 The Nairne model is on display at the Teylers' Museum in Haarlem while Paauw's machine stands next to Musschenbroek's model at the Boerhaave Museum in Leiden, catalogued as inventaris nr. A 33.

8 This is not to say that Paauw did not advertise his work; he relied on the rather typical means of appending instrument catalogues to his publications. See, for example, Paauw (1775). As for Blakey, he demonstrated his invention with an attractive copper model in London – obtaining a patent in 1766 – as well as with a small machine in a mine at Coalbrook Dale. His sponsor, James Ferguson, F.R.S., promoted his work in *Gentleman's Magazine* (August 1769, p. 392) and his own writings. See Ferguson (1823) (I have only been able to consult the third edition), volume I, pp. 312–314. In France, Blakey demonstrated his invention for members of the *Académie des Sciences* and the *Académie Royale d' Architecture*, winning official approbation from both societies.

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